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SYSTEMS WHICH RECOGNIZE ALPHANUMERIC SYMBOLS RECORDED ON A PAPE--ETC(U)
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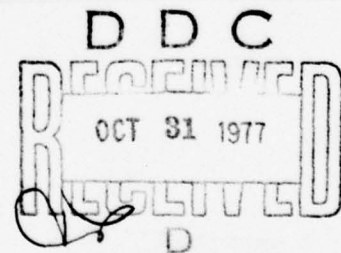
FOREIGN TECHNOLOGY DIVISION



SYSTEMS WHICH RECOGNIZE ALPHANUMERIC SYMBOLS
RECORDED ON A PAPER OR FILM BEARER

by

Z. Kedzior



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WP-AFB, OHIO.

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FIRST LINE OF TEXT

SYSTEMS WHICH RECOGNIZE ALPHANUMERIC SYMBOLS RECORDED ON A PAPER OR FILM BEARER

M. A. Enginerr, Zbigniew Kedzior

1. INTRODUCTION

Information handling is especially interested in systems which manage to read-off alphanumerical symbols directly from the original documents. For the giant quantities of data processed through digital machines, automata are necessary that read, which would replace a human in the process of preparing data, i.e., would shorten the time of introduction of data, as a result of which there are obtained additional economical effects.

From the point of view of the principle of operation, the systems that read alphanumeric characters can be assigned to the three following groups[1].

1. Optical readers of symbols.
2. Readers of symbols recorded in magnetic ink.
3. Readers of symbols recorded on a film bearer.

The greatest interest is enjoyed by the readers of group 1, called a systems of optical character recognition (OCR). This is the most numerous group from the point of view of number of types.

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On the markets of the western European countries, of the USA, and of Japan there are currently available more than 50 types of this kind of reader. Around 30 firms are occupied by the production of this kind of system. These systems read off the symbols of stylized machine writing (typing) as well as of ordinary typewriters and line-printers. Many of them read hand written numerical symbols in accordance with suitable rules (so-called hand printing). In Table 1 there are offered the parameters of several selected types of OCR systems of the production of American firms (data from the years 1972-1973). In the USSR similarly there are produced several types of alphanumeric symbol readers, as for instance the reader RUTA 701 and the Sever (north) 3.

Besides the above mentioned, to group 1 there can be numbered readers of symbols completed by coding dashes, as well as readers of dashes. These systems developed in the period when OCR technology was on a low level. Readers of dashes have spread in western European countries and Canada, however one must hope that in the future the demand for this type of system will decrease from the point of view of (on grounds of) the dynamic development of the optical technology of recognizing alphanumeric symbols.

The readers of group 2 arose also more or less at the same time as the readers of dashes and of symbols with coding dashes. In these readers the technology of recording assures a greater reliability of read-off, but on the other hand establishes very high requirements relating to the quality of printing, which makes difficult and increases the costs of use. The prices of commercial systems are relatively high and oscillate between limits of \$34,000 and \$123,000. The symbols of magnetic writing are readable with difficulty by a human. These systems currently do not enjoy interest. Their traditional use is the reading of checks in banks. In recent years there are not encountered new types of this kind of systems.

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FIRST The most modern systems are the readers of group 3. They represent a high precision of read-off of alphanumeric symbols, as well as the possibility of recognizing graphical information. In the range of character recognition there is used here the same technology as in the systems of group 1. The number of types of print read is very great; the speed of read-off is relatively large. A certain difficulty here is the transposing to the bearing film, i.e., the filming of documents, but on the other hand the information recorded in this manner is simple to preserve. A factor of difficulty in their spreading is above all their very high prices. Only two firms are known which produce these systems: Compuscan (first copy (model) produced in the year 1970) and Information International (first copy in the year 1971).

Summarizing the above it is possible to say that among the new and simultaneously with prospects one must count only optical readers of alphanumeric characters recorded on paper and film bearers. For this reason in the course of the discussion below there will be talk only of this type of systems.

2. REASONS FOR THE LITTLE SPREAD OF READERS

Factors which make difficult the spread of OCR systems are the high prices as well as the requirements relating to the quality of the printing. In the year 1970 there were in use around 1000 systems that recognized numerical and alphanumerical characters. Their prices varied within limits of from 25 thousand to one million dollars. Moreover the prices of the two mentioned types of microfilm system (without optics) amount to respectively \$900,000 compuscan 370 OCR system, and \$1.5 million -Graphix Reader of the firm Information International. The requirements

relative to the high quality of the print discourage users. For improvement of the use-parameters the manufacturers use stylized writing (printing). Similarly as for readers of characters recorded with magnetic ink or readers of characters with coding dashes, the stylized prints make difficult the spread of the character recognition systems.

Users must read-off documents completed on special writing machines. Meanwhile, the manufacturer are using, up till today, various types of stylized writing [2]. In the majority of readers produced contemporaneously it is necessary to use special forms (to fill out) (including checking digits, read-off field, controlling symbols, or cancelling dashes). During a change of the type of data read it is necessary to plan new types of forms. The requirements relating to the quality of paper also are high.

3. DIVISION OF SYSTEMS AND THEIR USE

From the users point of view optical readers of characters recorded on a paper bearer are divided into:

- a) document readers
- b) page readers
- c) readers of pages and documents
- d) readers of recording tape.

Document readers are systems which read-off information in selected places (so-called fields) of a form. The information read-off contains predominantly not more than 200 characters; readoff fields are located in one or two lines. The parameter that characterizes the speed of operation is the speed of the documents read, which depending on the type of system varies between limits of 60 to 1200 documents/minute. In these systems there is used predominantly read-off of numerical characters.

FIRST However page readers are systems which read all the characters appearing on documents. The significant parameter here is the speed of character reading (400-3600 chars./sec). Page readers recognize alphanumeric characters. In this group there are encountered universal systems that have a capability of recognizing many types of machine writing and hand written numerical characters, with a possibility of reading off documents of various forms as well as with many other advantages.

The above two types of systems differ from one another basically in mechanical construction. They are exploited in various spheres.

For users with a great range of applications there are produced universal systems (group C), which either have two transporting mechanisms or very fast mechanisms applied to the transport of small and large documents. The readers of group d read off characters recorded on a tape or recording cassettes or of arithmometers; they recognize only machine numerical characters and some special symbols. They have limited application. Hence the number of types available on the market is small (moreover many systems of groups a, b, and c are supplied, as an option, with a tape transport mechanism.).

Readers of characters recorded on film bearers are page readers. OCR systems are used most numerously (I sphere of applications) for the conversion of proofs of payment (turnaround applications) such as:

- . checks (credit)
- . proofs of payment (receipts) for electric energy and gas
- . proofs of payment of taxes, of insurance collections, subscriptions
- . lottery tickets

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FIRST Another sphere of applications is the conversion of documents arising in the framework of a single institution (in-house applications), in which there is a computing center (banks, industrial enterprises, public use institutions).

In the USA, in Great Britain, and in the Federal Republic of Germany there exist OCR service bureaus. These are centers of preparation of data from documents supplied by the clients (customers). The read off data are registered on magnetic tapes, paper tapes or punched cards.

FIRST LINE OF TITLE

A third sphere is field applications. Here representatives of firms (agents, travelling agents) fill out definite forms, which are read off by machine in a center.

4. POTENTIAL BUYERS IN POLAND

Some government institutions (statistical offices, the printing industry, the post office) are interested in the acquisition of automatic read off systems for information recorded on various kinds of documents and writings. Other institutions and offices, in view of the significant amount of information preserved and processed at their place, can be paid attention to as potential buyers and users of character readers.

In the opinion of the author such institutions as the patent office of the Polish People's Republic, printing (ind.) and many libraries must have at their disposal systems that read characters recorded on microfilm. The post office, many computing centers, commercial houses, and tourist bureaus must use direct read-off from documents. Moreover statistical offices must take advantage also of document reading systems, as also the information carried on a film bearer.

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It would be necessary to mention still another sphere of OCR applications, namely the exploitation of read-off subsystems (see paragraph 5.1.) or of complete character readers in reading rooms for the blind.

5. PRINCIPLES OF CONSTRUCTION OF OCR SYSTEMS

5.1. Electronic Subsystems

On Figure 1 there is presented a simplified schematic block diagram of the/a reader. The basic electronic systems of the electronic character reader are: the receptor or read-off subsystem, as well as the classifier or recognizer subsystem. In the continuation there are discussed types of designs of the above mentioned subsystems.

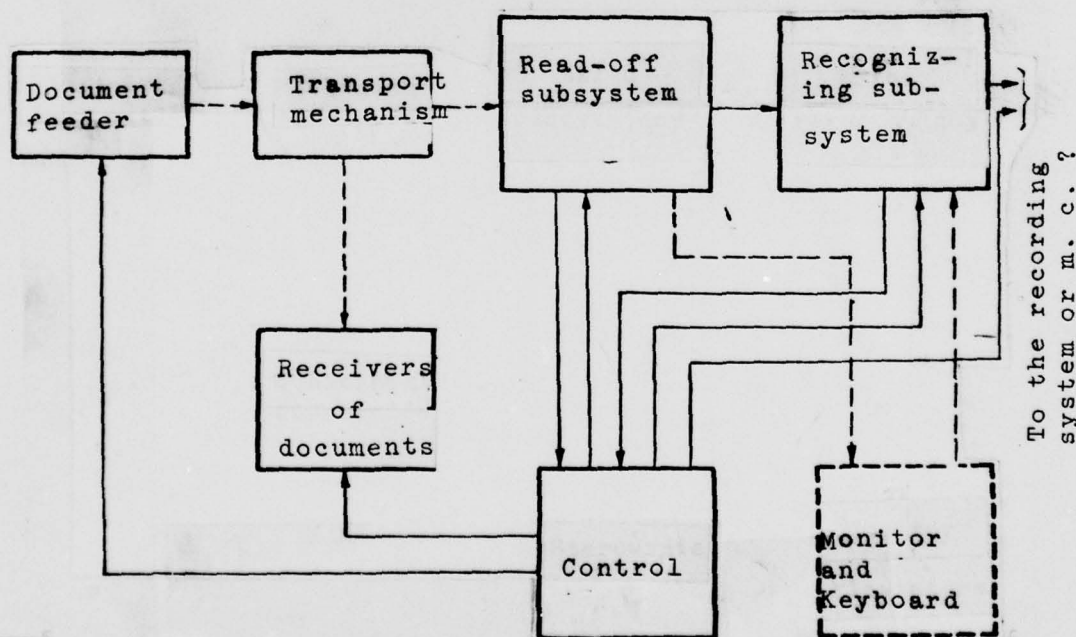


Figure 1. Schematic block diagram of the alphanumeric character reader (callouts).

Read-off Subsystems

Receptors of contemporaneously built optical readers of characters make good exploit use of the following read-off techniques:

- a. Relative motion of the documents under a column or retina of photoelements,
- b. Illumination of the points of a character raster by a narrow beam of non-coherent light (beam) guided by a system of moving mirrors with respect to illumination with the help of a rotating shield with apertures,
- c. Illumination of the points of a raster by a narrow beam of light, of a radiating tube (lamp) method of the mobile spot),
- d. read-off with the help of an accumulating tube (lamp),
- e) investigation of the contour of the character.

The read-off technique mentioned in point a) gives a high read-off speed but is costly. A design of type b) is among the cheapest, however its read-off speed is not great.

The techniques a) and b) belong to the most popular. The method of the moving spot makes possible the simplification of the mechanism, however it is a very costly method, while the speed of read-off is average (for instance in Filco-Ford's M6000 reader it amounts to 1250 characters/sec with an alphanumeric character read-off).

In the method d) the speed of read-off depends on the type of tube used which can be either a vidicon or a tube of the image disector tube type. In the first case the speed is small (250-500 characters/sec.) and in the second average (2000 characters/s). This method has not spread widely. In readers currently for sale there are not found any designs with tubes of the vidicon type.

However only in one reader (type 20/20 of the firm Seean Optics is there exploited an image detector tube (a tube built above all for optical recognition.)).

The method e) gives an average speed of read-off. Above all it finds application in the recognition of hand-written characters.

Recognizing Subsystems

The methods of recognition used in available readers on the markets of the western countries can be assigned to two groups:

- a) the method of matching to standards,
- b) the method of analysis of features.

The method of fragments (stroke analysis) and the method of analysis of tangents to segments of the contour (curve tracing) can be considered as subgroups of the analysis of features. Method a) is used for recognition of machine written characters. There are here attained the highest speeds of read-off (up to 3600 character/sec.). It is very popular. Its disadvantage is its lack of the possibility of recognition of handwritten characters. The majority of methods from the analysis of features group are applied to the recognition of hand-written characters or in systems that read-off several types of print. The method of fragments constitutes an exception which is not suited to the analysis of handwritten characters. In several readers there are applied simultaneously two methods: one for recognition of machine characters (a) and the other for handwritten (b).

An Example of a Design

The below presented is an abbreviated description of the type H8959 reader of the Hitachi firm (Japan) [2], a model of

which was produced in the year 1973. This is a page reader which recognizes hand written numerical characters or alphanumeric machine characters. It constitutes an example of a simple and simultaneously modern design. The receptor of the reader is of the electromechanical type, in which there is exploited a source of laser light (laser).

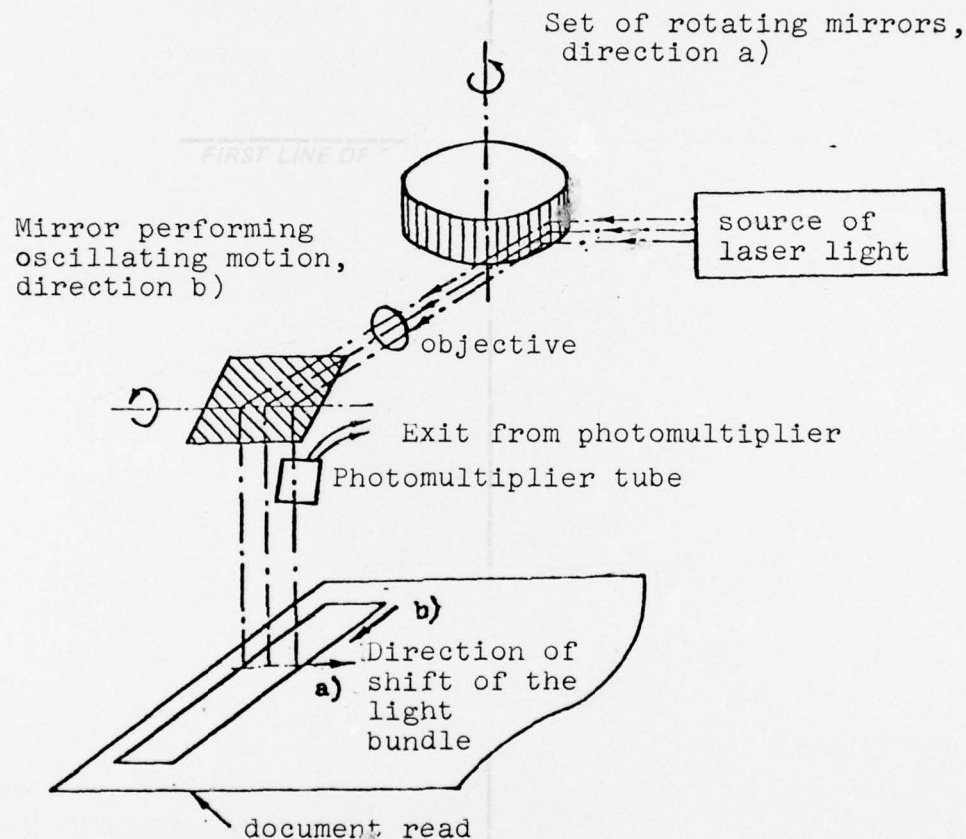


Figure 2. Kinetic schematic diagram of the electromechanical subsystem for read-off that appears in the Hitachi firm's H8959 reader.

On Figure 2 there is presented a kinetic schematic diagram of the read-off subsystem. A suitable setting up of hand mirrors in a system of rotating mirrors as well as the selection of the speed of this system to the time of the oscillations of a (single)

handmirror that performs an oscillatory motion, cause a successive (in time) shifting of the very narrow bundle of light emitted by the laser (mechanical scanning), in the very same way as takes place in a television system. The little arrows on the diagram make possible investigation of the direction of the shift of the laser radiation along the document. The light reflected from the paper is received by the photomultiplier tube and then is amplified and converted into digital signals.

The application of a coherent source in the technique of read-off gives many advantages, among which the most important is the improvement in the signal-to-noise ratio. This makes possible better distinguishing of the blackened places from the non blackened, and also does not require the use of complicated multi-stage amplifiers. The above design of a received is distinguished by it's low costs. The speed of read-off is not great in view of the use of a mechanical deviation (scanning) system.

In a recognition system there are mutually distinguished two basic systems (sets) namely:

- the introductory conversion system
- the recognition subsystem proper

During character recognition of handwriting in the introductory conversion system there are realized among others the following functions:

- normalization of the dimensions
- completion of breaks in the lines of a character
- the removal of darkened places not associated with characters.
- shading (actually a process of horizontal averaging).

FIRST The above mentioned functions are carried out by logical subsystems. The results of the operation of these subsystems can be illustrated in an example of the processing of the symbol "2" (Figure 3a and b).

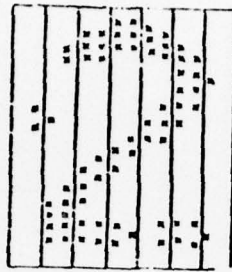
The signals of the shaded (averaged) picture are introduced into the recognizing system in which there occurs a division of the lines of the character (symbol) into sections with an approximate direction coefficient to the tangent to the curve, and it assigns a chain of code and finally recognizes. All possible directions of the tangent to the lines of the character are reduced to the eight directions of a wind-rose, to which there are assigned the digits 0 to 7. As a result of the operation of a special logical network, to each recognized character there gets assigned a final sequence (or chain) of digits, on the basis of which the recognition of the character is done. The manner of building of the chain of code is illustrated by Figure 3 (c and d).

The above method of recognizing handwritten characters which contains among other functions such as the elimination of disturbances (noise) (the completion of breaks, and the ridding of blotches) as well as shading (averaging) are modern features. Handwritten characters cannot be written arbitrarily. This means that a person filling out a document must be familiar with the rules of writing (Figure 4).

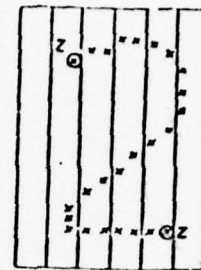
	Correct	Wrong										
Do not connect the characters to one another	<table><tr><td></td><td></td><td>1</td><td>0</td><td>0</td></tr></table>			1	0	0	<table><tr><td></td><td></td><td>1</td><td>0</td><td>0</td></tr></table>			1	0	0
		1	0	0								
		1	0	0								
The line of the characters cannot have breaks	<table><tr><td>8</td><td>6</td><td>9</td><td>7</td><td>5</td></tr></table>	8	6	9	7	5	<table><tr><td>8</td><td>6</td><td>9</td><td>7</td><td>5</td></tr></table>	8	6	9	7	5
8	6	9	7	5								
8	6	9	7	5								
The form of the characters must be simple and without "hooks (tails)"	<table><tr><td>7</td><td>2</td><td>4</td><td>1</td><td>0</td></tr></table>	7	2	4	1	0	<table><tr><td>7</td><td>2</td><td>4</td><td>1</td><td>0</td></tr></table>	7	2	4	1	0
7	2	4	1	0								
7	2	4	1	0								

Figure 4. Supplementary training for persons filling out documents with handwriting.

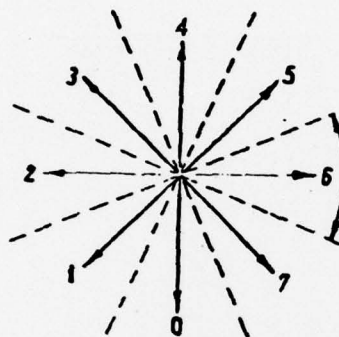
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a) Matrix of the input signals



b) Matrix of the shaded (averaged) signals



c) Manner of marking of directions



d) Manner of coding the characters being recognized

Figure 3. Graphic illustration of the functions realized in a recognition subsystem for hand written characters in the H8959 reader.

For recognition of machine printed characters in the H8959 reader there is applied the conventional method of fitting masks (standards).

The classification system accepted here recognizes up to 50 different types of characters simultaneously. The selection of the standards for each type of machine print is mounted in the form of one set. In case of changing the type of machine print it is necessary to change this set for another.

Basic Parameters of the H8959 Reader

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Basic Parameters of the H8959 Reader

1) Types of writing (print):

• numerical characters by hand calligraphy as well as the symbols C, S, T, X and Z

• machine stylized numerical symbols of the type OCR-A, OCR-B, 407 (IBM) and 12F (Farrington)

Options

• alphanumeric stylized characters OCR-A

• numerical characters of various machine types for writing

2) The system reads-off simultaneously (i.e., from a single document) machine and hand numerical symbols

3) Dimensions of the documents from 145 x 95 to 300 x 220 mm

4) Maximum number in a line

• of hand characters - 36

• of machine characters - 72

5) Maximum number of lines on a document

• with hand characters - 25

• with machine characters - 29

6) Maximum speed of read-off

• of hand characters - 50 characters/sec

• of machine characters - 100 characters/sec

• forms (to be filled out) - 36 documents/min

7) Output vehicle for the data: paper tapes

8) Dimensions of the system in mm (without a paper tape punch): 1160 x 630 x 1360

• weight: around 360 kg

• dimensions of the paper tape punch - 490 x 425 x 340 mm

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9) The permissible temperature and humidity of the surrounding area of the system: 5 - 35° C and 30 - 85% relative humidity.

From the above data there results that the parameters of the system are less than the parameters of many readers of firms such as REJ, CDC, Scan Data Corporation, or IBM. The H8959 system has limited possibilities in the area of the number of characters happening to be on one document, in the area of the number of types of writing (print), is distinguished also by small speed of read-off. On the other hand however, it is a system of small dimensions and according to opinions belongs among the relatively cheap.

5.2. Mechanisms of Moving Documents

The most complicated are the mechanisms of document readers and of page readers. In modern systems there are applied friction feeds, vacuum ones as well as ones with conical wheels. In the area of transport mechanisms there are used vacuum drums. Modern receivers exploit drum mechanisms. Mechanisms appearing in contemporaneously produced readers are relatively costly. There exists an opinion [1] that their cost of production constitutes 50% of the costs of the whole reader.

6. OPERATIONS CARRIED ON IN POLAND

For several years in the Institute for Organizations and Direction of PAN (Polish Academy of Science(s)) there have been carried on equally basic researches as well as certain applied operations in the field of recognition. There is developing here a biocybernetic direction (trend) which strives toward the construction of a model of an artificial neuron network that simulates the human nervous system, as well as a program direction occupied with the seeking of general principles of

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Table 1. List of some types of alphanumeric optical character readers manufactured by AMERICAN companies.

Kind	Type	Manufacturer	BASIC PARAMETERS			
			Document Feed-speed, pieces/min	Reading speed, characters/sec.	Number of characters on document	Types of script read and characters
			4	5	6	7
Document Reader	2703 Document Reading Systems	UNIVAC	300:600	1500	1 line, up to 80 characters	OCRA and UNIVAC H, 14 numerical and special characters
	921 Document Reader	CDC	1200	2210	1 line, up to 80 characters	OCRA, 7B, OCRB - numerical
Page Reader	1288 Optical Page Reader	JPM	14 328	1000	84 lines, up to 96 characters/lines	OCRA alphanumeric; hand-print, numerical
	Model 6000 Print Reader	Philco-Ford	160-360	1250	78 lines, up to 90 characters/lines	Several machine print types, upper and lower case alphanumeric letters
Microfilm Page Reader	370 OCR System	Compuscan	No data	400 4000	No exact data	arbitrary machine font; alphanumeric characters
Page and Document Reader	System 70	Cognitronics	to 60	250	Optional number of lines, up to 76 character/lines	Machine numerical - several repertoires and numerical hand-printing; options: OCRA or OCRB - alphanumeric
	Model 250		50:180	800	81 lines, up to 100 characters/lines	1-5 types of machine print type, upper and lower case alphanumeric characters; more repertoires - optional
Tape Reader	Model 4040	Lundy-Farrington	2000 lines/min.	2000	to 32 characters/lines	numerical 12F, 7B, OCRA, NCR NOF, 1428/+ up to 8 special characters

(Table continues reading left to right).

Data Output	Document Size, (mm)	Operational Method	Year when first model was manufactured	DOLLAR COST USA	
				System	System with options
8	9	10	11	12	13
Directly to computer	from 67, 7x76 to 108x222	Column of photoelements and matching of masks	1970	42000	64 560
Magnetic tape	from 66x114 to 114x229	Laser beam and matching of masks	1971	no data	61 000
Directly to computer	from 76x166 to 227x355	Moving spot-method	no data	223 390	296 480
Magnetic tape, punched cards, paper tape, directly to computer	from 127x178 to 216x229	Moving spot-method and matching of masks	1965	400 000	296 480 no data
Directly to computer	microfilm tape 16 or 35 mm	Moving-spot method, matching of masks, and feature analysis	1970	900 000	no data
Magnetic tape, paper tape, punched cards	from 102x82.5 to 227x355	Laser beam and feature analysis	1970	33 600	41 250
Magnetic tape, paper tape, punched cards	from 127x76	Moving spot method and feature analysis	1971	215 000	315 000
Magnetic tape	-	Moving spot method	1969	no data	no data

recognition with the help of simple operations realized through an electronic digital machine, or a specialized system. These operations touch on many disciplines for recognizing objects, and in this number, of recognizing alphanumeric characters as well as graphic information. Among others there has been (is being) worked on here and put into operation, a model of a system which reads alphanumeric characters, of machine print with a speed of read-off of up to 40 characters/second.

7. TENDENCIES IN THE BUILDING OF OCR SYSTEMS

For the reading off of characters there is beginning to be used a source of coherent light. This design assures above all a large signal-to-noise ratio, of the analog signals received by the receptor, through which the accuracy of the read-off is increased, and also it is possible to use lower grades of paper as well as to eliminate darkness in the environment of the read-off head. This design is used in commercial readers such as: the Cognitronics firm's System 70 (1970), 921 DR of the CDC firm, (1971) as well as the reader described in section 5.1 page reader type H8959 of the Hitachi firm (1973).

At a conference on the OCR theme, which took place in the year 1967 in Delft (Holland) there was discussed the possibility of exploiting holography for character recognition [3]. Researches in this direction are (being) carried on in many countries. However, up to this time there is a lack of information about the sale of readers that exploit the phenomenon of holography.

Lately more and more frequently there is used a system called context recognition, in which there is analyzed the type of neighboring characters along with those recognized.

FIRST In modern designs there is used a two-stage analysis. First of all there are recognized the so-called small features (local) and then there is carried through a final identification within the framework of a group of characters that have shapes that are close. There is used also "supplementary instruction" in the case of the appearance of characters of deviated shapes or even a certain learning carried out by the user.

There have been carried out operations on the recognition of handwritten alphabetic characters, the result of which is a proposal to state standards pertaining to handwritten characters [5].

In the face of little demand due to the high prices, the manufacturers have begun to build significantly cheaper systems specialized for concrete applications.

8. PROPOSALS

In the face of the growth of applications of computers in recent years in Poland, there is an increasing number of potential purchasers of alphanumeric character readers. Since systems of this type are very costly it would be necessary currently to begin suitable preparatory operations, as a result of which it would be possible to obtain desired technical results at the least possible costs. For this purpose it would be necessary to determine a uniform cut of types for all newly bought typewriters from import and from native production, and especially of those that will be used for executing source documents for data conversion.

It is necessary to set up an institution which would accept for its self the sphere of applications of OCR systems. This niche among others must take on itself the matter of the supplying

of future users of systems with printed materials of native production assuring a high quality of printing (forms for machine read-off, paper grades and tapes for typewriters).

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